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QUANTITATIVE SURVEY OF INTERTIDAL ORGANISMS ON ROCKY SHORES IN MUTSU BAY, WITH SPECIAL REFERENCE TO THE INFLUENCE OF WAVE ACTION[1)]

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Typical zonation was recognized by the quantitative observation of intertidal organisms at 2 stations in Mutsu Bay, where were influenced by the different strength of wave action. The number of individuals, biomass and number of species observed were more abundant at the station of strong wave action than at the station of weak wave action. Poor fauna observed at the station of weak wave action may be attributed to the unfavorable environmental condition influenced by sand, mud and detritus deposited beneath the mussel zone. In Mutsu Bay the eulittoral zone was reasonably devided into 2 sub-zones, the barnacle- and mussel-zones. The mussel-zone, which was large in number of species and abundant in biomass, formed a characteristic intertidal community composed of animals possessing various life mode. Smaller individuals of *Mytilus edulis* were collected at the upper part of the mussel zone and the larger at the lower part.

INTRODUCTION

Up to this time, many investigations have been done as to intertidal organisms on rocky shores, paying a special ecological attention to "zonation", and its nature and formation mechanisms have been reported (COLMAN 1933, STEPHENSON and STEPHENSON 1949, SOUTHWARD 1958a, LEWIS 1964, EVANS 1950). Desiccation, temperature and wave action have been considered as important environmental factors to determine the distribution of intertidal organisms (STEPHENSON and STEPHENSON 1949, DOTY and ARCHER 1950, BARNES and BARNES 1957, SOUTHWARD 1958b. CONNEL 1961, LEWIS 1964, KENSLER 1967, LUCKENS 1968, 1969, FOSTER 1969, 1971a, b) and the mode of settlement and the presence of predator as biological factors (CRISP and BARNES 1954, CONNEL 1961, LUCKENS 1970). LEWIS (1964) and GLYNN (1965) studied the food relations of intertidal organisms and presented a scheme of food web, and PAINE (1969, 1974), CONNEL (1970) and DAYTONE (1971) studied prey-predator relations in an intertidal community.

Though there are many investigations as to intertidal organisms as above, the branch of community ecology remains still more unexploited yet. The author will attempt a synecological approach to intertidal rocky shore organisms in Mutsu Bay.

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1) Contribution from the Marine Biological Station, Tôhoku University, No. 431

2) 土屋 誠

Hoshiai (1958, 1959, 1960, 1964, 1965) studied an intertidal community in detail. He showed the distribution of principal animals and discussed the reformation of zonation on denuded rocks. But a quantitative description on whole intertidal organisms was not always sufficient. Because a quantitative description is required for analysing the community, the author conducted a quantitative survey at the rocky shores having a very typical intertidal zonation in Mutsu Bay.

STUDY AREA AND METHODS

Two stations were selected at the rocky shores with different strength of wave action (Fig. 1). One was at the west side of rocky shore at Hadakajima Island near the Asamushi Marine Biological Station, Tôhoku University, where was influenced by extreme strong wave action in Mutsu Bay, and another at the land side of the Breakwater in Aomori Harbor, where was quiet all the year round. 55 years have passed after the construction of this Breakwater. Field survey was done during ebb tide in April, 1977 on the spot of typical zonation of intertidal organisms. The composition and structure of the community were determined based on samples of 10×10 cm quadrat. All organisms were continuously scrapped off at each level from extreme low water of spring tides (ELWS) to the upper limit of organisms area. A qualitative sampling and field observation were also carried on to know the fauna at each station. Samples were fixed in 10% formalin, and later in the laboratory the number of individuals and biomass (wet weight in gr. with shell) were recorded for each species. Shell length of the mussels, *Mytilus edulis* and *Septifer* (*Mytilisepta*) *virgatus* was also measured.

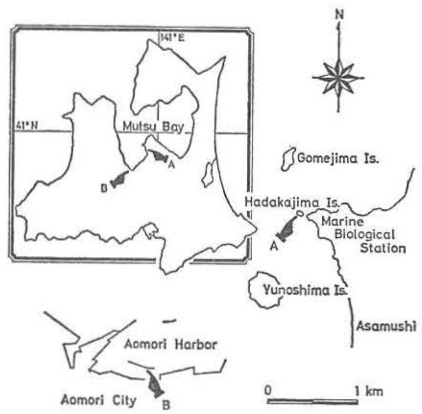


Fig. 1. Study area. A: rocky coast of Hadakajima Island.
B: the Breakwater of Aomori Harbor.

RESULTS

General condition of the sea shore

First, general climatic and oceanographic conditions of the study sites, including air temperature, water temperature, chlorinity, tide curve and the wind direction during 1977–1978 are shown in Fig. 2. These values were obtained from the records of daily observation at the sea shore in the front of the Asamushi Marine Biological Station and the records of the tide table at Aomori Marine Observatory.

Distribution of intertidal organisms

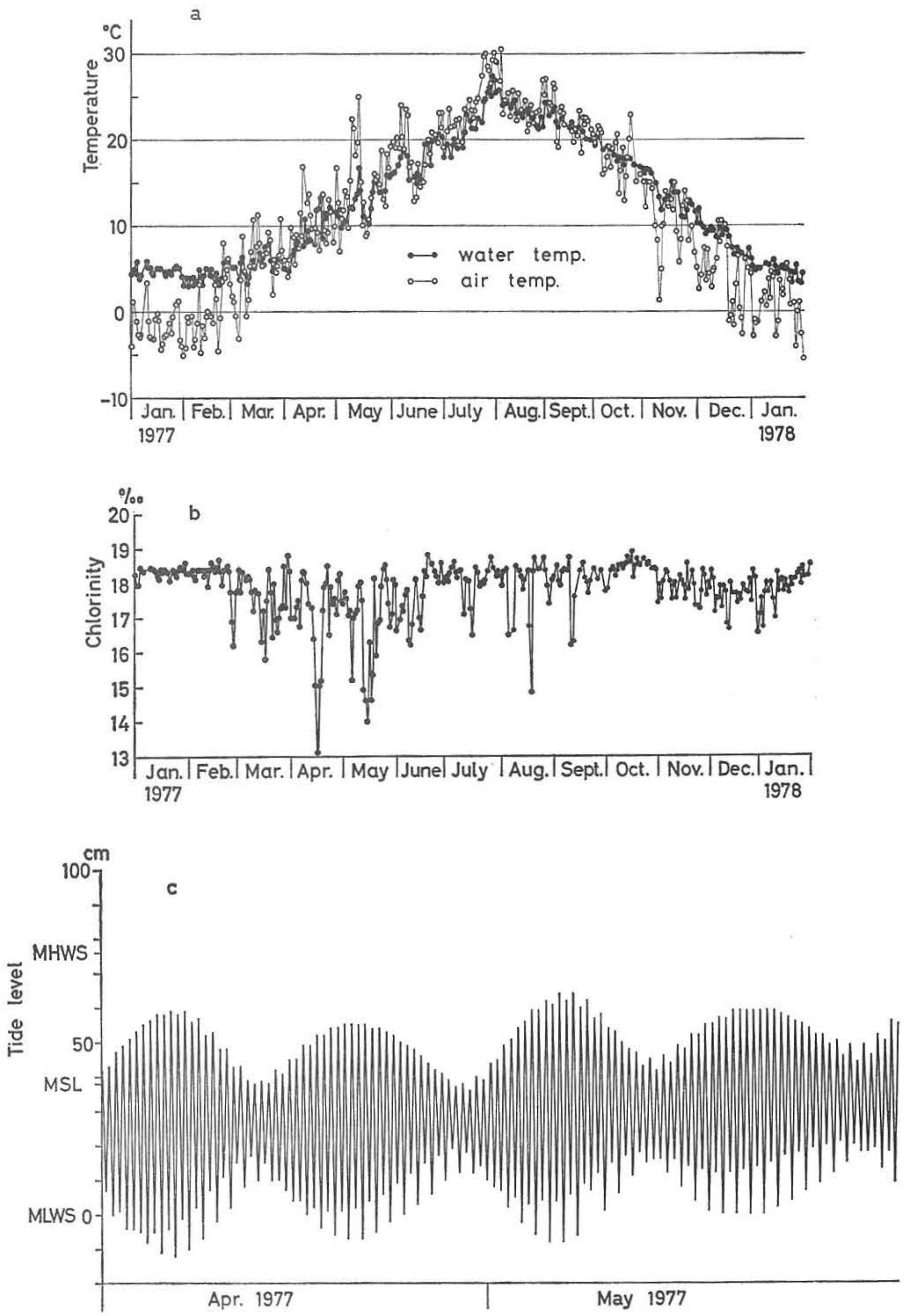
1) Hadakajima Island

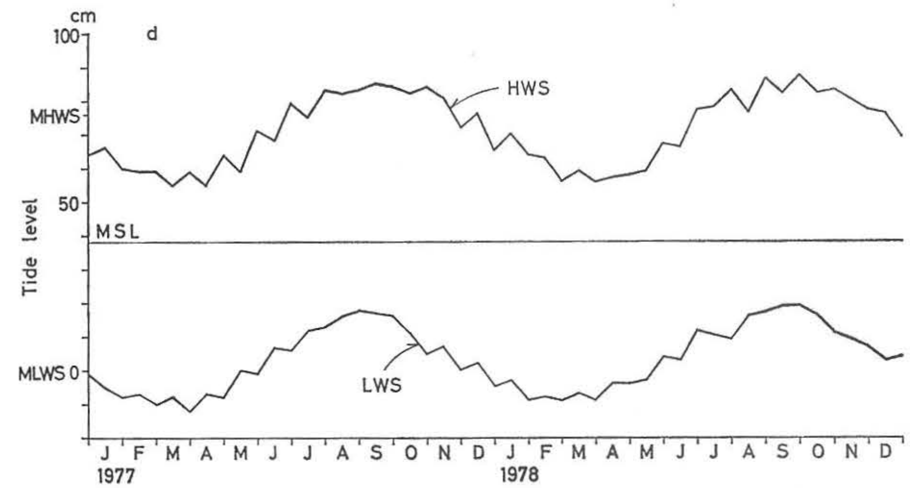
The vertical distribution of intertidal organisms at the rocky shore of Hadakajima Island is shown in Fig. 3. The intertidal zone is devided into three zones in connection with tide level and distribution of organisms, i.e. "Periwinkle", "Barnacle" and "Mussel" zones. Organisms living in each zone at Hadakajima Island are as follows:

"Periwinkle zone" The periwinkles *Nodilittorina granularis* and *Littorina brevicula* occupy the higher levels of the intertidal and sprash zone. *N. granularis* lives in the highest levels of intertidal zone and mostly uses the rock crevice. Maximum density of *N. granularis* was 23 per 100 cm^2 with biomass of 1.4 g at 140 cm level above mean low water level of spring tides (MLWS) (all density and biomass described in the following are shown as the number per 100 cm^2). *L. brevicula* inhabits the lower place than *N. granularis* and penetrates further down into the zones dominated by barnacles and mussels. 23 individuals were collected at 80 cm level and its biomass was 2.2 g. The isopod *Ligia* (*Megaligia*) *exotica* is frequent above high water mark and wanders about wide area to the mussel zone at low tide. The harpacticoid *Tigriopus japonicus* and larvae and pupae of the mosquite *Aedes togoi* occur in the tide pools in this level. The vertical range of periwinkle zone was about 80 cm.

"Barnacle zone" The barnacle *Chthamalus challengeri* covered 70–80% of rock surface at 70–100 cm level. Maximum density was 480 individuals at 80 cm level and maximum biomass 48.5 g at 75 cm level. This barnacle produced the conspicuous yellowish grey zone, the upper limit of which was remarkably sharp about 120 cm above MLWS. In the low-density part the individual barnacles show the normally conical form, but when the density increases many barnacles become elongate and columner in shape as already described by Kato *et al.* (1959, 1960a, b, c). *C. challengeri* is widely distributed and attaches also on the mussels at the lower part of intertidal zone.

Within this barnacle zone *Littorina brevicula* remains abundant in the dead barnacles and gap of it. At a steep gradient place near the level of the upper limit of *C. challengeri*, a gathering of the limpet *Collisella dorsuosa* may be seen.





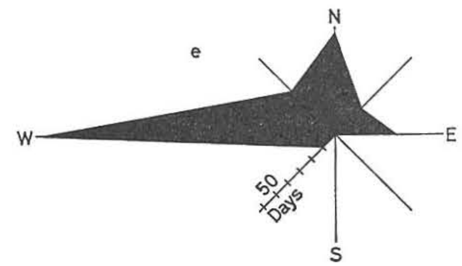
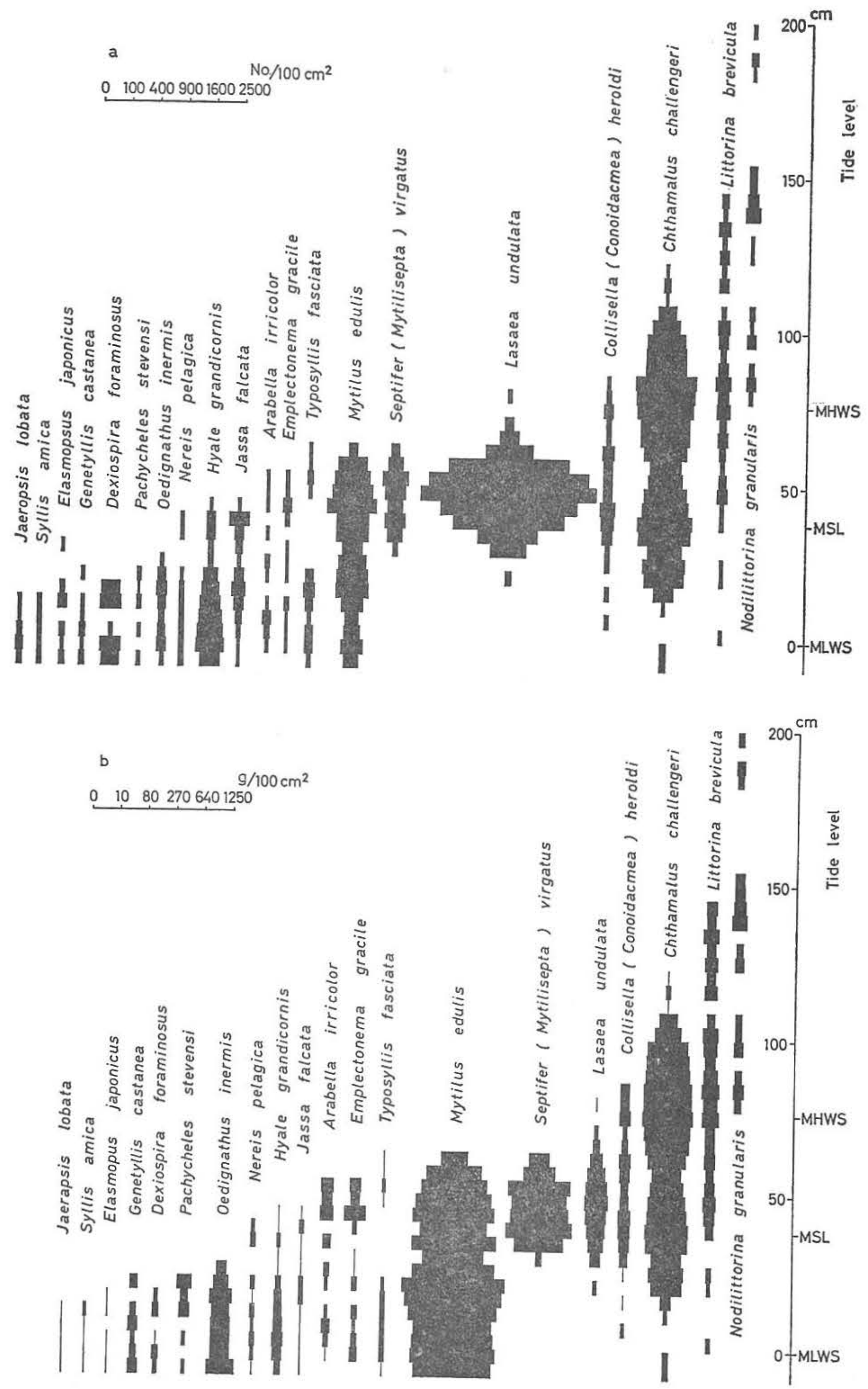


Fig. 2. General environmental conditions.
a: Seasonal change of air temperature and water temperature during 1977.
b: Seasonal change of chlorinity of surface layer during 1977.
c: Tidal behavior curve during April through May, 1977.
d: Seasonal change of high water of spring tides (HWS) and low water of spring tides (LWS).
e: Frequency of the wind direction.

"Mussel zone" The upper limit of the mussels, *Septifer* (*Mytilisepta*) *virgatus* and *Mytilus edulis*, is sharply defined than that of *C. challengeri* and sudden change of color make the "mussel line" the most conspicuous feature of this shore. The vertical range of the mussel zone was about 65 cm. *S.* (*Mytilisepta*) *virgatus* was distributed at 30–65 cm level. Its maximum density was 83 individuals at 55 cm level and maximum biomass was 120.1 g at 40 cm level. *M. edulis* was distributed from 65 cm level to the subtidal zone. Its maximum density was 283 individuals at 45 cm level and maximum biomass was 472.0 g at 20 cm level. Fig. 3 (b) shows that the biomass of this species is the largest of all intertidal organisms.

The limpet *Collisella* (*Conoidacmea*) *heroldi* is a characteristic species in the eulittoral zone (the barnacle and mussel zones) and widely distributed. Its maximum density was 22 individuals with biomass of 0.8 g at 45 cm level.

Fauna observed in this zone is extremely diversed and large number of individuals and species live in a gap and underlayer of the mussels. The most abundant species is a small bivalve, *Lasaea undulata*, inhabiting mainly under the *S.* (*Mytilisepta*) *virgatus*. 3892 individuals and 5.0 g were collected at 50 cm level. Common organisms found under the mussels are as follows: the nemertine *Emplectonema gracile*, *Amphiporus cervicalsi*, the sipunculoid *Phascolosoma scolops*, the polychaetes



Harmothoë imbricata, *Eularia viridis*, *Typosyllis fasciata*, *Nereis pelagica*, *Arabella irricolor*, *Nainereis laevigata*, the crustaceans *Allorchestes plumicornis*, *Hyala grandicornis*, *Ampithoe lacertosa*, *Elasmopus japonicus*, *Jassa falcata*, *Pachycheles stevensi*, *Oedignathus inermis*.

In shallow tide pool at the lower level of the eulittoral zone, other animals, including the sea anemones *Anthopleura midori*, *A. japonica*, *A. pacifica*, *Metridium senile* var. *fimbriatum*, the gastropods *Mitrella tenius*, *Reticunassa fratercula*, the crustaceans *Pagurus samuelis*, *P. middendorfii*, *P. lanuginosus*, *Hemigrapsus sanguineus*, the seastars *Asterias amurensis*, *Aphelasterias japonica*, *Asterina pectinifera*, the fish *Chasmichthys dolichgnathus gulosus*, are found commonly.

Carnivorous gastropods *Thais clavigera* and *T. bronni* aggregate in the lower level of the eulittoral zone at their breeding season.

The lowest part of intertidal zone changes marked populations. The most of the species found in the mussel belt die out abruptly, and are replaced by the brown algae, including *Undaria pinnatifida*, *Sargassum tortile*, *S. thunbergii*, *S. hemiphyllum* and *S. kjellmanianum*. Beneath these large algae *Mytilus edulis*, *M. coruscus* and some bryozoans attach to the rock surface here and there.

Other fouling animals observed in this zone are as follows: the polifera *Halichoedria japonica*, the polychaetes *Pseudopotamilla occelata*, *Hydroides ezoensis*, *H. elegans*, *Dexiospira foraminosus*, the molluscs *Lepidozona* (*Gurjanovilla*) *albrechti*, *Acanthochiton rubrolineatus*, *Cellana torema*, *Cellana grata*, *Crassostrea gigas*.

2) Aomori Harbor

Fig. 4 shows the vertical distribution of intertidal organisms at the Breakwater of Aomori Harbor. Though general view of distribution in this station was similar to that of Hadakajima Island, fauna was poor in general as compared with that of Hadakajima Island. Organisms collected in this area are as follows:

"Periwinkle zone" The vertical range of *Nodilittorina granularis* was 70–170 cm level and its maximum density was 18 individuals at 160 cm level and maximum biomass was 1.1 g at the same level. *Littorina brevicula* occupies wider range than *Chthamalus challengeri* does and is distributed in the same zone dominated by *Mytilus edulis*. *L. brevicula* inhabiting the barnacle zone and the mussel zone were mostly smaller than 3 mm in shell height. Its maximum density was 320 individuals with biomass of 1.4 g at 40 cm level.

Together with the two periwinkles *N. granularis* and *L. brevicula*, *Ligia* (*Megaligia*) *exotica* are common in this zone, particularly in the crevice of the Breakwater.

"Barnacle zone" *C. challengeri* covers 60–80% of the surface in the level of 40–70 cm and small individuals of *C. challengeri* attach to the surface of *Mytilus*

Fig. 3. Vertical distribution of organisms at the rocky shore of Hadakajima Island. The number of individuals is shown in the upper figure (a) and the biomass in the lower figure (b).

shell. Maximum density of *C. challengeri* was 333 individuals with biomass of 36.2 g at 40 cm level. Small individuals of *Collisella* (*Conoidacmea*) *heroldi* are also collected in this zone.

"Mussel zone" The vertical range of the mussel zone, which was composed of only *Mytilus edulis*, was -10 to 40 cm level. Its maximum density was 344 individuals and its biomass was 264.3 g at 20 cm level. It is characteristic in this station that large amount of sand, mud and detritus, which were assumed to be blackned with bad smell, were deposited under the messel zone. At 20 cm level 11 individuals of the polychaete *Capitella capitata japonica* were collected in a quadrat in these materials. Common animals collected in this zone are as follows: the nemertine *Emplectonema gracile*, the polychaetes *Typosyllis fasciata*, *Nereis pelagica*, *Hydroides ezoensis*, the crustaceans *Balanus albicostatus*, *Jassa falcata*.

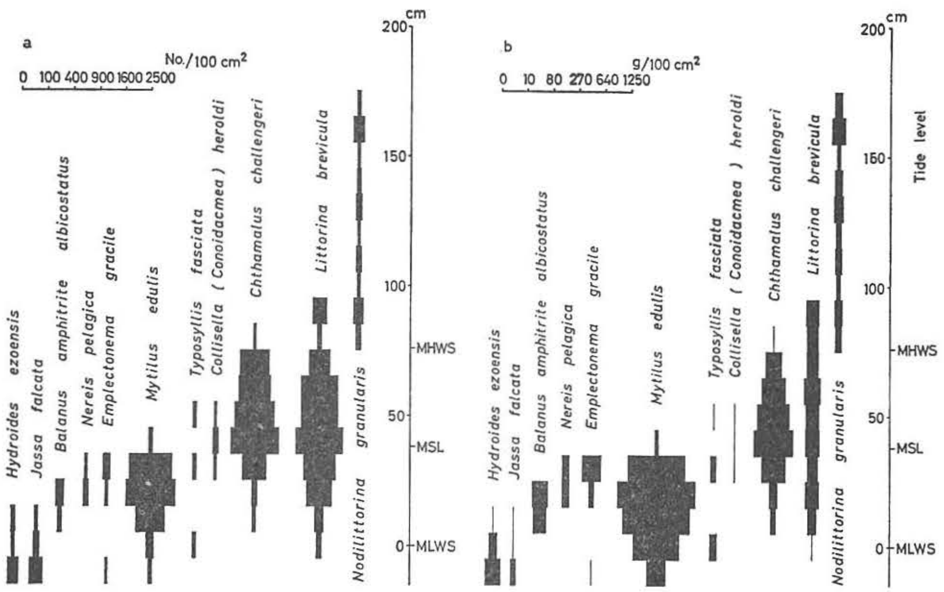


Fig. 4. Vertical distribution of organisms at the Breakwater of Aomori Harbor. The number of individuals is shown in the left figure (a) and the biomass in the right figure (b).

Number of individuals, biomass and number of species

Fig. 5 shows the number of individuals, biomass and number of species obtained from the quantitative survey at 2 stations. It is clear that animals observed at the upper part of the intertidal zone is less than that of the lower. At Hadakajima Island the upper limit of marine organisms was 2 m above MLWS in vertical distance. 4396 individuals were collected at 50 cm level and large number of individuals observed here was brought about by the presence of small bivalve *Lasaea undulata* which attached to the byssus of *Septifer* (*Mytilisepta*) *virgatus*.

Outside the range of *L. undulata* the number of individuals was below 500. 0–3.0 g of biomass was observed at 110–200 cm level above MLWS, and 30–80 g at 60–100 cm level, and over 200 g below 50 cm level, especially 487.8 g at 25 cm level. The number of species collected increased gradually to the level of above 20 cm level and 26–29 species of the macrobenthos were collected below 15 cm level.

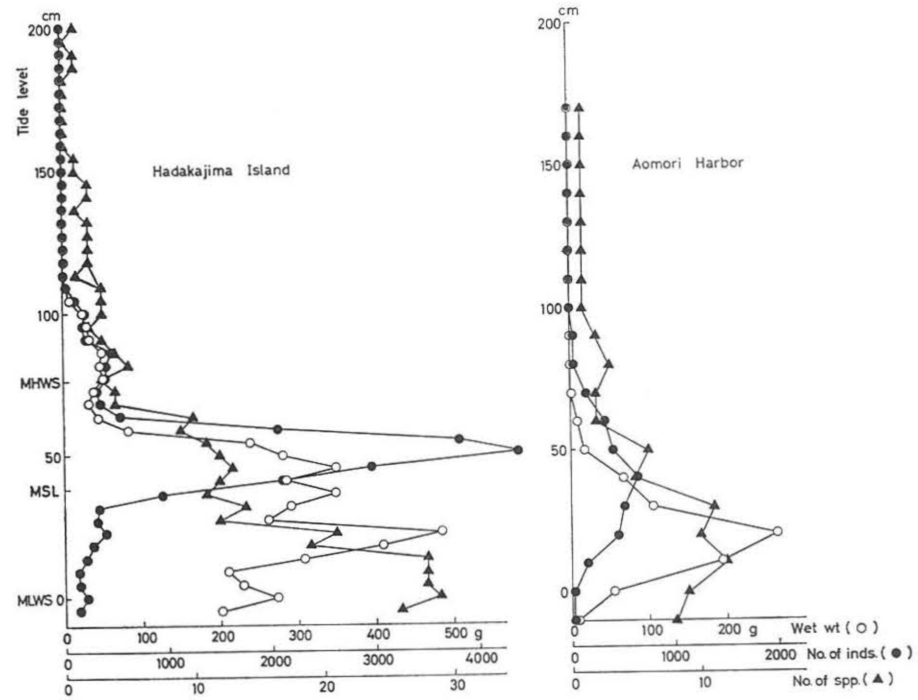


Fig. 5. Vertical distribution of the number of individuals, biomass and number of species at both stations.

On the other hand, amounts of organisms collected at the Breakwater of Aomori Harbor was less than that of Hadakajima Island. The upper limit of distribution extends to the top of the Breakwater and was 170 cm level above MLWS in this station. Only one species, *Nodilittorina granularis*, inhabited above 100 cm level. Total number of individuals was about 100–750 at 10–70 cm level and below 50 individuals was collected at other levels. Total biomass was also large at the lower level of the intertidal zone, especially 0–40 cm level, and maximum biomass was 268.8 g at 20 cm level. The number of species was also large at the lower level and 10 species were collected in a quadrat at -10 to 30 cm level.

Fig. 6 shows the size distribution of *Mytilus edulis* in connection with tide level at the rocky shore of Hadakajima Island and the Breakwater of Aomori Harbor. A same trend of size distribution was observed at both stations. Namely, the small individuals were collected from the upper part of the mussel zone and varied size of *M. edulis* were collected from the central part of this zone and large size of individuals were dominated near MLWS. Large number of individuals were collected at the upper part and it tended to decrease towards the lower part. The similar results were also obtained at Aomori Harbor, but this trend was not cinspicuous as compared with that of Hadakajima Island. The number of individuals was especially large at 20–30 cm level, and a few large-size individuals were collected at the MLWS level. The attachment of *M. edulis* was rare near MLWS and below it.

The trend of size distribution as above was not conspicuous as to *Septifer (Mytilisepta) virgatus* at Hadakajima Island.

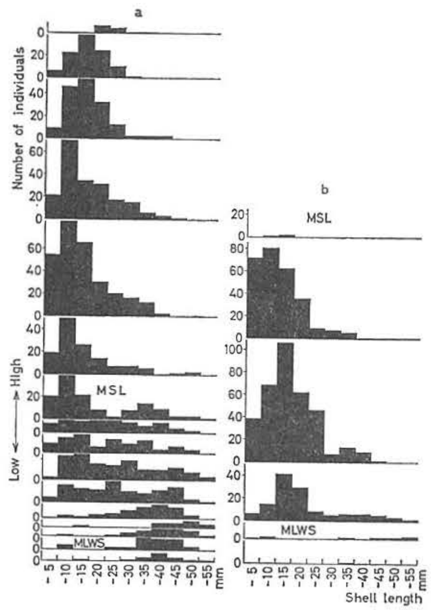


Fig. 6. Size distribution of *Mytilus edulis* collected at the rocky shore of Hadakajima Island (a) and at the Breakwater of Aomori Harbor (b).

DISCUSSION

It is well known that the vertical range of intertidal organisms at the rocky shores is related to the strength of wave action and the range become wider as wave exposure increased (LEWIS 1964, HOSHIAI 1965, GURJANOVA 1968). This fact was confirmed in this study and it was also cleared that the magnitude of biomass was related to the strength of wave action. Namely, the higher maximum biomass (487.9 g) was observed at the extremely exposed west side rocky shore of Hadakajima Island, while at the sheltered land side of the Breakwater of Aomori Harbor, maximum biomass was 268.8 g. The maximum number of individuals per 100 cm^2 was 4396 at the Hadakajima Island and 659 at the Breakwater of Aomori

Harbor, and the number of species collected by this quantitative survey was 72 and 32, respectively. There were differences between the number of individuals, biomass and number of species collected at Hadakajima Island and those at Aomori Harbor as above. The influence of wave action is considered as important factor to determine these differences between both stations. The number of species is influenced by abundance of small animals inhabited under the mussels. At Aomori Harbor large amounts of sand, mud and detritus were deposited under the mussel zone. This environment has a bad effect on these benthic animals and it follows that the number of species is small and the polychaete *Capitella capitata japonica*, which is an indicator species of polluted area, inhabit under the mussel zone. These materials deposited under *M. edulis* can not be wash away by the weak wave action, thus this environment may remain worse for benthic animals. In addition, oxygen is well supplied even under the mussel zone at Hadakajima Island and many macrofauna are able to inhabit this place.

The intertidal zone is devided into several sub-zones based on some conditions. COLMAN (1933) devided the intertidal zone into 3 sub-zones by tidal level on the basis of species composition, and WOMERSLEY and EDMONDS (1952) and STEPHENSON and STEPHENSON (1949) also devided in relation to the tidal level. LEWIS (1964) devided it on the basis of distribution of organisms. Since similar zonation described in this paper is observed at many locations in Mutsu Bay without reference to the strength of wave action, it is suitable to devide the intertidal zone into 3 sub-zones, the periwinkle-, the barnacle- and the mussel zone. The eulittoral zone, which is the range from the upper limit of the seaweed zone to the upper limit of the barnacle zone, is clearly separated into 2 sub-zones, the upper sub-zone dominated by the barnacle *Chthamalus challengeri* and the lower sub-zone dominated by the mussels *Septifer (Mytilisepta) virgatus* and *Mytilus edulis*, in Mutsu Bay as already recognized by HOSHIAI (1965). In the barnacle zone large number of individuals and small number of species are observed. At the lower part of the eulittoral zone, the mussel zone, many organisms inhabit under the mussels, and the number of individuals, and species and the biomass are large. These feature of zonation is commonly observed at the rocky shores in Mutsu Bay and Pacific coast of northeastern Japan.

Over 90% of total biomass was formed by *M. edulis* and *S. (Mytilisepta) virgatus* at the mussel zone. Since many animals living in this zone are given their habitat by the mussels, the rôle of mussels in the intertidal community is important. *M. edulis* have been observed after about 1948 in Mutsu Bay (YAMAMOTO & HABE 1958) and its distribution area has rapidly extended in whole Mutsu Bay. It seems that the invasion of *M. edulis* in Mutsu Bay has an important effect to the change of fauna or the community structure of intertidal zone.

Size of *M. edulis* collected becomes large toward the lower tide level. SENAWONG (1972) have obtained similar result as to *Hormomya mutabilis* at

Tanabe Bay, Wakayama Prefecture. These results may be explained as follows: The lower the tidal level, the longer the time submerged and consequently they may take the larger amounts of food. This seems to accelerate the growth of *M. edulis*, resulting the pattern of the size distribution on the rocky shores as described above. But more detail investigation must be done for analysis this problem considering their age composition and life cycle.

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REFERENCES

Barnes, H. and M. Barnes 1957. Resistance to desiccation in intertidal barnacles. Science, **126**, 358.

Colman, J. 1933. The nature of intertidal zonation of plants and animals. J. mar. biol. Ass. U.K., **18**, 435–476.

Connel, J. H. 1961. The influence of intertidal competition and other factors on the distribution of the barnacle *Chthamalus stellatus*. Ecol., **42**, 710–723.

Connel, J. H. 1970. A predator-prey system in the marine intertidal region. I. *Balanus glandula* and several predatory species of *Thais*. Ecol. Monogr., **40**, 49–78.

Crisp, D. J. and H. Barnes 1954. The orientation and distribution of barnacles at settlement, with particular reference to surface contour. J. Anim. Ecol., **23**, 142–162.

Daytone, P. K. 1971. Competition, disturbance and community organization: The provision and subsequent utilization of space in a rocky intertidal community. Ecol. Monogr. **41**. 351–389.

Foster, B. A. 1969. Tolerance of high temperature by some intertidal barnacles. Mar. Biol., **4**, 326–332.

Foster, B. A. 1971a. Desiccation as a factor in the intertidal zonation of barnacles. Mar. Biol., **8**, 12–29.

Foster, B. A. 1971b. On the determination of upper limit of intertidal zonation of barnacles (Crustaces: Cirripedia). J. Anim. Ecol., **40**, 33–48.

Glynn, P. W. 1965. Community composition, structure and interrelationshipps in the marine intertidal *Endocladia muricata-Balanus glandula* association in Monterey, California. Beaufortia, **12**, 1–198.

Gurjanova, E. F. 1968. The influence of water movements upon the species composition and distribution of the marine fauna and flora throughout the arctic and north Pacific intertidal zone. Sarsia, **34**, 83–94.

Hoshiai, T. 1958. Synecological study on intertidal communities. I. The zonation of intertidal animal community with special reference to the interspecific relation. Bull. Mar. Biol. St. Asamushi, **9**, 27–33.

Hoshiai, T. 1959. Synecological study on intertidal communities. II. On the interrelation between the *Hijikia fusiforme* zone and the *Mytilus edulis* zone. Bull. Mar. Biol. St. Asamushi, **9**, 123–126.

Hoshiai, T. 1960. Synecological study on intertidal communities. III. An analysis of interrelation among sedentary organisms on the artificially denuded rock surface. Bull. Mar. Biol. St. Asamushi, **10**, 49–56.

Hoshiai, T. 1964. Synecological study on intertidal communities. V. The interrelation between *Septifer virgatus* and *Mytilus edulis*. Bull. Mar. Biol. St. Asamushi, **12**, 37–41.

Hoshiai, T. 1965. Synecological study on intertidal communities. VI. A synecological study on the intertidal zonation on the Asamushi coastal area with reference to its reformation. Bull. Mar. Biol. St. Asamushi, **12**, 93–126.

Kato, M., K. Hayasaka and T. Matsuda 1959. Ecological studies on the morphological variation of a sessile barnacle, *Chthamalus challengeri*. Bull. Mar. Biol. St. Asamushi, **9**, 187–191.

Kato, M., K. Hayasaka and T. Matsuda 1960a. Ecological studies on the morphological variation of a sessile barnacle, *Chthamalus challengeri*. I. Changes of the external appearance introduced by the population density. Bull. Mar. Biol. St. Asamushi, **10**, 1–7.

Kato, M., K. Hayasaka and T. Matsuda 1960b. Ecological studies on the morphological variation of a sessile barnacle, *Chthamalus challengeri*. II. Constitutional characters of the *Chthamalus* population with special reference to the stratication of the *Chthamalus* zone. Bull. Mar. Biol. St. Asamushi, **10**, 9–17.

Kato, M., K. Hayasaka and T. Matsuda 1960c. Ecological studies on the morphological variation of a sessile barnacle, *Chthamalus challengeri*. III. Variation of the shell shape and of the inner anatomical feature introduced by the population density. Bull. Mar. Biol. St. Asamushi, **10**, 19–25.

Kensler, C. B. 1967. Desiccation resistance of intertidal crevice species as a factor in their zonation. J. Anim. Ecol., **36**, 391–406.

Lewis, J. R. 1963. Environmental and tissue temperatures of some tropical intertidal marine animals. Biol. Bull., **124**, 277–284.

Lewis, J. R. 1964. The ecology of rocky shores. 323 pp. English Univ. Press, London.

Luckens, P. A. 1968. The breeding and settlement of *Chthamalus challengeri* Hoek at Asamushi during 1967. Bull. Mar. Biol. St. Asamushi, **13**, 75–82.

Luckens, P. A. 1969. The breeding and settlement of *Chthamalus challengeri* Hoek at Asamushi during 1968. Bull. Mar. Biol. St. Asamushi, **13**, 259–254.

Luckens, P. A. 1970. Predation and intertidal zonation at Asamushi. Bull. Mar. Biol. St. Asamushi, **14**, 33–52.

Paine, R. T. 1969, The *Pisaster-Tegula* interaction. Prey patches, predator food preparation and intertidal community structure. Ecol., **50**, 950–961.

Paine, R. T. 1974. Intertidal community structure. Experimental studies on the relationship between a dominant competitor and its principal predator. Oecologia, **15**, 93–120.

Senawong, C. 1972. Biological studies of a littoral mussel, *Hormomya mutabilis* (Gould). III. Distribution of *Hormomya* and *Modiolus* on Hatakejima Island. Pub. Seto Mar. Biol. Lab., **19**, 269–291.

Southward, A. J. 1958a. The zonation of plants and animals on rocky sea shores. Biol. Bull., **38**, 137–177.

Southward, A. J. 1958b. Note on the temperature tolerences of some intertidal animals in relation to environmental temperatures and geographical distribution. J. mar. biol. Ass. U.K., **37**, 49–66.

Southward, A. J. and J. H. Orton 1954. The effect of wave-action on the distribution and numbers of the common plants and animals living on the Plymouth breakwater. J. mar. biol. Ass. U.K., **33**, 1–19.

Stephenson, T. A. and A. Stephenson 1949. The universal features of zonation between tide-marks on rocky coast. J. Ecol., **37**, 289–305.

Womersley, H. B. S. and S. J. Edmonds 1952. Marine coastal zonation in southern Australia in relation to a general scheme of classification. J. Ecol., **40**, 84–90.

Yamamoto, G. and Habe 1958. Fauna of shell-bearing molluscs in Mutsu Bay. Lamellibranchia (1). Bull. Mar. Biol. St. Asamushi, **9**, 1–20.

APPENDIX TABLE

A list of intertidal macrofauna collected in this survey.
cc: very common, c: common, +: present, −: not observed.

No.	PHYLUM		Station	
	Species	Japanese name	Asamushi	Aomori Harbor
	PORIFERA			
1.	*Halichondria japonica* (KADOTA)	Daidaiisokaimen	c	−
2.	*Halichondria okadai* (KADOTA)	Kuroisokaimen	+	+
	COELENTERATA			
3.	*Anthopleura midori* UCHIDA *et* MURAMATSU	Midoriisoginchaku	c	+
4.	*Anthopleura japonica* VERRILL	Yoroiisoginchaku	c	−
5.	*Anthopleura pacifica* UCHIDA	Hiodoshiisoginchaku	c	+
6.	*Metridium senile* var. *fimbriatum* VERRILL	Hidaberiisoginchaku	+	−
7.	*Haliplannella luciae* (VERRILL)	Tatejimaisoginchaku	+	−
8.	*Epiactis japonica* (VERRILL)	Komochiisoginchaku	c	−
	PLATHELMINTHES			
9.	*Notoplana humilis* (STIMPSON)	Usuhiramushi	c	c
10.	*Stylochus ijimai* YERI *et* KABURAKI	Iijimahiramushi	+	−
	NEMERTINEA			
11.	*Coia ijimai* TAKAKURA	Iijimahimomushi	+	−
12.	*Emplectonema gracile* JOHNSTON	Hosomidorihimomushi	c	c
13.	*Amphiporus cervicalis* (STIMPSON)	Yajirobehimomushi	c	+
	SIPUNCULOIDEA			
14.	*Phascolosoma scolops* (SELENKA *et* DE MAN)	Samehadahoshimushi	+	+
15.	*Sipunculus nudus* LINNÉ	Sujihoshimushi	+	−
16.	*Siphonosoma cumanense* (KEFERTEIN)	Sujihoshimushimodoki	+	−
	ANNELIDA			
17.	*Harmothoë imbricata* (LINNÉ)	Madaraurokomushi	+	+
18.	*Lepidonotus helotypus* GRUBE	Sanhachiurokomushi	c	−
19.	*Lepidonotus elongatus* MARENZELLER		+	+
20.	*Halosydna brevisetosa* KINBERG	Mirokuurokomushi	+	+
21.	*Genetyllis castanea* (MARENZELLER)	Akenosashiba	+	−
22.	*Eularia viridis* (LINNAEUS)	Samidorisashiba	+	+
23.	*Eularia viridis japonensis* IMAJIMA & HARTMAN		+	−
24.	*Typosyllis fasicata* (MALMGREN)	Monoshirisu	c	c
25.	*Typosyllis adamanteus kurilensis* CHLEBOVITSH		+	c
26.	*Tyopsyllis* sp. A		+	+
27.	*Typosyllis* sp. B		+	+
28.	*Syllis amica* QUATERFAREDE		+	−
29.	*Exogone gemmifera* (CLAPAREDE)		+	−
30.	*Autolytus* sp.		+	+
31.	*Trypanosyllis (Trypanosyllis) zebra* (GRUBE)	Shimashirisu	+	−
32.	*Pseudonereis variegata* (GRUBE)		+	−
33.	*Nereis heterocirrata* TREDWELL		+	−
34.	*Nereis pelagica* LINNAUS	Futsûgokai	c	c

Appendix Table Continued

No.	Species	Japanese name	Asamushi	Aomori Harbor
35.	*Nereis zonata* MALMGREN		+	−
36.	*Nereis vexillosa* GRUBE	Ezogokai	+	+
37.	*Nereis* sp.		+	+
38.	*Lumbrineris japonica* (MARENZELLER)	Giboshiisome	c	−
39.	*Lumbrineris nipponica* IMAJIMA		+	−
40.	*Arabella irricolor* (MONTAGU)	Seguroisome	c	c
41.	*Arabella* sp.		+	−
42.	*Dorvillea matsushimaensis* (OKUDA et YAMADA)	Akasujiisome	+	−
43.	*Marphysa sanguinea* (MONTAGU)	Iwamushi	+	+
44.	*Spio* sp.		−	+
45.	*Cirriformia tentaculata* (MONTAGU)	Mizuhikigokai	+	+
46.	*Cirratulus cirratus* (O.F. MÜLLER)	Chigusamizuhiki	+	+
47.	*Acrocirrus muroraensis* OKUDA	Ezokumanoashitsuki	+	−
48.	*Capitella capitata japonica* KITAMORI		−	c
49.	*Nainereis laevigata* GRUBE	Tsuburahokomushi	c	−
50.	*Polyophthalmus pictus* (DUJARON)	Kasuriopheria	+	−
51.	*Abarenicola pacifica* HEALY & WELLS	Isotamashikigokai	+	−
52.	*Pseudopotamilla occelata* MOORE	Erako	c	−
53.	*Nicolea gracilibranchis* (GRUBE)		+	−
54.	*Thelepus japonicus* MARENZELLER		−	+
55.	*Amphitrite* sp.		+	−
56.	*Hydroides ezoensis* OKUDA	Ezokasanekanzashi	c	c
57.	*Hydroides elegans* (HASWELL)	Kasanekanzashi	+	+
58.	*Pomatoleios kraussii* (BAIRD)	Yakkokanzashi	c	−
59.	*Dexiospira spirillum* (LINNAEUS)	Subekawauzumaki-gokai	+	−
60.	*Dexiospira foraminosus* (BUSH)	Uzumakigokai	c	c
	TENTACULATA			
61.	*Amathia distans* BUSK	Tsubunarikokemushi	+	−
62.	*Bowerbankia imbricata* ADAMUS	Sennarikokemushi	+	−
63.	*Bowerbankia caudata* HINCKS	Chibiofukuro-kokemushi	+	−
64.	*Valkeria uva* (LINNÉ)	Itokokemushi	+	−
65.	*Bugula neritina* (LINNÉ)	Fusakokemushi	+	−
66.	*Beania mirabilis* JOHNSTON	Narabikokemushi	+	−
67.	*Tricellaria occidentalis* (TRASK)	Hosofusakokemushi	+	+
68.	*Dakaria subovoidea* (D'ORBIGNY)	Chigokemushi	+	+
69.	*Celleporina costazii* (AUDOUIN)	Kobukokemushi	+	−
	MOLLUSCA			
70.	*Ischnochiton* (*s.s.*) *comptus* f. *comptus* (GOULD)	Usuhizaragai	+	−
71.	*Ischnochiton* (*Ischnoradsia*) *hakodatensis* (PILSBRY)	Hakodatehizaragai	+	−
72.	*Lepidozona* (*Gurjanovilla*) *albrechti* (SCHRENCK)	Ezoyasurihizaragai	c	−
73.	*Placiphorella japonica* (DALL)	Babagase	+	+
74.	*Placiphorella stimpsoni* (GOULD)	Kitanobabagase	+	−
75.	*Rhyssoplax kurodai* (Is.TAKI et Iw. TAKI)	Kusazurigai	+	−
76.	*Liolophura japonica* (LISCHKE)	Hizaragai	+	+
77.	*Acanthochiton rubrolineatus* (LISCHKE)	Himekehadahizaragai	c	+
78.	*Acanthochiton defilippii* (TAPPARUNE-CANEFRI)	Kehadahizaragai	+	−
79.	*Nordotis discus* (REEV)	Kuroawabi	+	−
80.	*Cellana grata* (GOULD)	Bekkokasagai	+	c

Appendix Table Continued

81.	*Cellana toreuma* (Reeve)	Yomegakasagai	c	–
82.	*Tugalina gigas* (v. Martens)	Saruawabigai	+	+
83.	*Patelloida* (*Chizacmea*) *pygmaea* (Dunker)	Himekozaragai	+	–
84.	*Acmaea* (*Niveotectura*) *pallida* (Gould)	Yukinokasagai	+	+
85.	*Collisella dorsuos* (Gould)	Kamogai	c	c
86.	*Collisella* (*Conoidacmea*) *heroldi* (Dunker)	Kogamogai	c	c
87.	*Collisella pelta shirogai* Habe et Ito	Shirogai	+	–
88.	*Notoacmea concinna* (Lischke)	Kôdakaaogai	c	+
89.	*Notoacmea schrenckii* (Lischke)	Aogai	c	+
90.	*Cantharidus japonicus* (A. Adams)	Chigusagai	+	–
91.	*Cantharidus jessoensis* (Schrenck)	Ezochigusagai	+	+
92.	*Tristichotrochus multiliratus* (Sowerby)	Nishikiebisugai	+	–
93.	*Monodonta labio* (Linné)	Ishidatamigai	c	–
94.	*Monodonta* (*Neomodonta*) *neritoides* (Philippi)	Kurotsukegai	+	–
95.	*Omphalius rusticus* (Gmelin)	Koshidakagangara	c	c
96.	*Chlorostoma argyrostoma turbinata* (A. Adams)	Hesoakikubogai	c	+
97.	*Lunella coronata* (Gmelin)	Sugai	+	–
98.	*Littorina brevicula* (Philippi)	Tamakibigai	c	c
99.	*Littorina mandschurica* Schrenck)	Atsutamakibigai	+	–
100.	*Nodilittorina granularis* (Gray)	Araretamakibigai	c	c
101.	*Temanella turrita* (A. Adams)	Chairotamakibi	c	+
102.	*Truncatella* (*Tahetia*) *pfeiffer* v. Martens	Kyushukubikiregai	c	–
103.	*Angustassiminea satsumana* Habe	Satsumakawazanshô	c	–
104.	*Serpulorbis* (*Cladopoda*) *imbricatus* (Dunker)	Oohebigai	+	–
105.	*Batillaria cumingii* (Crosse)	Hosouminina	+	–
106.	*Ocenebra japonica* (Dunker)	Oouyôrakugai	c	c
107.	*Ceratostoma burnetti* (A. Adams et Reeve)	Hiregai	+	+
108.	*Nucella freycineti* (Deshayes)	Ezochijimibora	+	–
109.	*Thais clavigera* (Küster)	Ibonishi	c	+
110.	*Thais bronni* (Dunker)	Reishigai	c	c
111.	*Mitrella tenuis* (Gaskoin)	Kôdakamatsumushigai	c	+
112.	*Searlesia modesta* (Gould)	Ezoisonina	+	–
113.	*Neptunea arthritica* (Bernardi)	Himeezobora	+	–
114.	*Reticunassa fraterculas* (Dunker)	Kurosujimushirogai	c	+
115.	*Haloa japonica* (Pilsbry)	Budôgai	c	–
116.	*Aplysia* (*Varria*) *kurodai* (Baba)	Amefurashi	c	–
117.	*Aplysia* (*Pruvotaplysia*) *parvula* Mörsh	Kuroheriamefurashi	+	–
118.	*Petalifera punctulata* (Tapparone-Canefi)	Uminamekuji	+	–
119.	*Homoiodoris japonica* Bergh	Yamatoumiushi	+	–
120.	*Dendrodoris* (*Dendrodoris*) *rubra nigromaculata* (Eliot)	Madaraumiushi	+	–
121.	*Siphonaria* (*Sacculosiphonaria*) *japonica* (Donjvan)	Karamatsugai	+	–
122.	*Arca navicularis* Bruguiere	Koberutofunegai	+	–
123.	*Barbatia* (*Savignyarca*) *virescens* (Reeve)	Kariganeegai	+	–
124.	*Pseudogrammatodon dalli* (Smith)	Shikoroegai	+	–
125.	*Septifer* (*Mytilisepta*) *virgatus* (Wiegamann)	Murasakiinkogai	c c	–

Appendix Table Continued

126.	*Mytilus edulis* Linné	Murasakiigai	c c	c c
127.	*Mytilus coruscus* Gould	Igai	c	+
128.	*Modiolus modiolus difficilis* (Kuroda et Habe)	Ezohibarigai	+	–
129.	*Crassostrea nippona* (Seki)	Iwagaki	+	–
130.	*Crassostrea gigas* (Thunberg)	Magaki	c	c
131.	*Ostrea circumpicta* Pilsbry ?	Kokegoromogaki ?	+	–
132.	*Lasaea undulata* (Gould)	Chirihagigai	c c	–
133.	*Tapes* (*Amygdala*) *philippinarum* (A. Adams et Reeve)	Asari	+	–
134.	*Claudiconcha japonica* (Dunker)	Semiasari	+	–
	ARTHROPODA			
135.	*Lecythorphynchus hilgendorfi* (Böhm)	Shimaumigumo	+	–
136.	*Pollicpies mitella* (Linné)	Kamenote	+	–
137.	*Chthamalus challengeri* Hoek	Iwafujitsubo	c c	c c
138.	*Balanus* (*Megabalanus*) *rosa* Pilsbry	Akafujitsubo	+	c
139.	*Balanus albicostatus* Pilsbry	Shirosujifujitsubo	+	c
140.	*Balanus cariosus* (Pallas)	Chishimafujitsubo	+	+
141.	*Paranthura japonica* Richardson	Uminanafushi	+	–
142.	*Cirolana harfordi japonica* Thielmann	Nisesunahorimushi	+	+
143.	*Exosphaeroma ovata* Gurjanova	Marukotsubumushi	+	–
144.	*Dynoides dentisinus* Shen	Shirikenumisemi	c	c
145.	*Synidotea laevidorsalis* Miers	Warajiheramushi	+	–
146.	*Idotea ochotensis ochotensis* Brandt	Ohôtsukuheramushi	+	+
147.	*Cleantiella isopus* (Grube)	Isoheramushi	+	–
148.	*Cleantiella strasseni* (Thielmann)	Ohirakiheramushi	+	–
149.	*Jaeropsis lobata* Richardson	Hirataumimizumushi	+	–
150.	*Ligia* (*Megaligia*) *exotica* Roux	Funashimu	c c	c c
151.	*Parhyale ochotensis* (Brandt)	Futaashimokuzu	+	+
152.	*Allorchestes plumicornis* (Heller)	Fusagemokuzu	+	–
153.	*Hyale grandicornis* (Kröyer)	Mokuzuyokoebi	+	–
154.	*Ampithoe lacertosa* Bate	Nipponmobayokoebi	c	c
155.	*Melita koreana* Stephensen	Kagimeritayokoebi	+	–
156.	*Elasmopus japonicus* Stephenson	Isoyokoebi	+	+
157.	*Jassa falcata* (Montagu)	Kamakiriyokoebi	c	c
158.	*Caprella acutifrons* Laterille	Maruerawarekara	c	+
159.	*Caprella scarua* Templeton	Togewarekara	+	–
160.	*Caprella danilevskii* Czerniawski	Hosowarekara	+	–
161.	*Caprella aequilibra* Say	Kubinagawarekara	+	–
162.	*Caprella acanthogaster* Mayer	Ibarawarekara	+	–
163.	*Petrolisthes japonicus* (De Haan)	Isokanidamashi	+	–
164.	*Pachycheles stevensi* Stimpson	Kobukanidamashi	+	–
165.	*Pagurus germinus* McLaughlin	Honyadokari	c	+
166.	*Pagurus lanuginosus* De Haan	Keashihonyadokari	c	c
167.	*Pagurus dubius* (Ortmann)	Yubinagahonyadokari	+	–
168.	*Pagurus middendorfii* Brandt	Tenagahonyadokari	+	–
169.	*Oediganthus inermis* (Stimpson)	Ibogani	c	+
170.	*Hapalogaster dentata* (De Haan)	Ibotogegani	+	–
171.	*Pugettia quadridens* (De Haan)	Yotsuhamogani	+	–
172.	*Cancer amphioetus* Rathbun	Koichogani	+	–
173.	*Pachygrapsus crassipes* Randall	Iwagani	+	–
174.	*Hemigrapsus sanguineus* (De Haan)	Isogani	c	c
175.	*Gaetice depressus* (De Haan)	Hiraisogani	+	–
	ECHINODERMATA			
176.	*Ophiopholis mirabilis* (Duncan)	Madarakumohitode	+	–

Appendix Table Continued

177.	*Asterina pectinifera* MÜLLER *et* TROSCHEL	Itomakihitode	c	c
178.	*Hennicia nipponica* UCHIDA	Himehitode	+	–
179.	*Asterias amurensis* LÜTKEN	Hitode	c	c
180.	*Aphelastrias japonica* (BELL)	Ezohitode	c	+
181.	*Hemicentrotus pulcherrimus* (A. AGASSIZ)	Bafununi	+	–
182.	*Strongylocentrotus intermedius* (A. AGASSIZ)	Ezobafununi	+	–
183.	*Strongylocentrotus nudus* (A. AGASSIZ)	Kitamurasakiuni	c	–
184.	*Cucumaria chronhjelmi* THÉEL	Ishiko	+	–
	PROTOCHORDATA			
185.	*Amaroucium pliciferum* REDIKORZEV	Manjûboya	+	–
186.	*Botrylloides violaceus* OKA	Akaitaboya	c	–
	VERTEBRATA			
187.	*Chasmichthys dolichognathus gulosus* (GUICHENOT)	Dorome	c	–